

CHAPIN, (C.V.)

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## SOME POINTS IN THE ETIOLOGY OF TYPHOID FEVER.<sup>1</sup>

BY CHARLES V. CHAPIN, M.D.,

*Superintendent of Health, Providence, R. I.*

In the excellent paper just read Dr. Swarts has presented a resumé of the experimental work which has established the diagnostic worth of the typhoid bacillus, and he has also presented the experimental evidence of the etiological as well as diagnostic importance of the organism. As long as our knowledge of typhoid in the lower animals remains as uncertain as it is at the present time, it is unwise to base any conclusions as to the etiological rôle of the bacillus upon the laboratory experiments which have been made upon these animals. It is only by similar experiments made upon man that the actual rôle of the organism can be positively determined, and such experiments are of course not permissible. I therefore consider of the greatest value certain clinical evidences, if I may so call them, of the causative relation of the bacillus to typhoid in the human subject. If we can find the bacilli in water or other media which we know to have caused the disease, we shall have evidence of very great weight of the pathogenic property of the organism.

In epidemics of greater or lesser magnitude, traceable to drinking-waters, the water has in a number of instances been examined for the bacilli.

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*resigned by the author.*

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That they have not always been found need not surprise one who is at all familiar with the difficult processes of bacteriological analysis. Even such skilled observers as Gaffky<sup>2</sup> at Wittenburg, Kock and Cramer<sup>3</sup> at Zurich, Simmonds<sup>4</sup> at Hamburg, and Rietsch<sup>5</sup> at Pas des Lanciers were unable to detect the bacilli, although the water was certainly the cause of the epidemics observed at the above-named places. On the other hand, we have as positive evidence the finding the bacilli in a well at Mulheim,<sup>6</sup> the water of which was known to have caused typhoid in fourteen persons. Beumer<sup>7</sup> found it at Greifswald under similar circumstances, and so did Rodet at Sous-Ville-Charmoux,<sup>8</sup> and Arloing at Cluny.<sup>9</sup> Widal<sup>10</sup> found it in Paris, and Chantemesse at Clermont-Ferrand<sup>11</sup> and Pierrefonds.<sup>12</sup> The latter was a particularly interesting case, as large numbers of the bacilli were found in a well — twenty-five thousand to the litre — the water of which caused typhoid fever in every one of a party of twenty persons who came there from Paris, and who drank the water. There was no typhoid elsewhere in the place at the time. The chemical analysis of the well did not indicate any great pollution; indeed, was better than the neighboring wells in which the bacilli were not found, and which did not cause the disease. In Italy the bacillus has been found in drinking-water which was the cause of the disease, by two observers.<sup>13</sup>

<sup>2</sup> Mitt. aus d. k. k. Gesundhtsamt., ii. p. 372, 1884, Berlin.

<sup>3</sup> Deut. Vtjschr. f. öff. Gesundhtspflg., 1886, xviii. 537.

<sup>4</sup> Deut. Vtjschr. f. öff. Gesundhtspflg., 1886, xviii. p. 142.

<sup>5</sup> Jour. de l'anat. et phys., Paris, 1886, xxii. 224.

<sup>6</sup> Erganz. zum Cbl. f. alg. Gesundhtspflg., ii. 2, p. 133, 1886.

<sup>7</sup> Deut. med. Woch., 1887, No. 28.

<sup>8</sup> Lyon. méd., 1887, lvi. 583.

<sup>9</sup> Lyon. méd., 1887, lvi. 371, 414.

<sup>10</sup> Gaz. heb., 1886, p. 726.

<sup>11</sup> Ann. d'hyg., 1887, 3. s. xviii. p. 385.

<sup>12</sup> Gaz. heb., 1886, 2. s. xxiii. p. 829.

<sup>13</sup> Rivista intern. di med. e chir., 1887, No. 8. La Riforma med., 1886, No. 277-79. Abstract — Baumgarten's Jahresbericht, 1887.

Kowalski<sup>14</sup> found it at Vienna in 1886, and da Rocha<sup>15</sup> at Coimbre. In this country, Vaughn<sup>16</sup> found it in water which caused an epidemic at Iron Mountain, and in air which produced the disease at the Michigan State Prison.<sup>17</sup> At Cincinnati, in 1887, there was a moderate epidemic of typhoid, and Rochford<sup>18</sup> found the typhoid bacilli in the city water. In all, there are thirteen recorded instances in which the bacillus of Eberth has been found in waters known to have caused typhoid, and once in air. Since this organism is so constantly found in cases of typhoid, in the essential lesions of the disease, and in the evacuations of the patient, which are known to be contagious, and since it has been found repeatedly in water and air which were known to cause the disease, we are forced to the conclusion that it is the essential factor in its production. And this is rendered still more certain by the negative evidence of its absence, as shown by repeated biological examinations of drinking-water, as at Pierrefonds mentioned above, and by the fruitless search that has been made for it in other diseases. In a paper published in 1885 I said that there was no good evidence that the so-called typhoid bacillus of Eberth was really the cause of the disease; but since that time the evidence has accumulated so that one is justified in considering the germ theory a theory no longer, so far as typhoid fever is concerned.

Our present knowledge of this disease explains many things which were formerly a great puzzle to us, and reconciles what were apparently contra-

<sup>14</sup> Internat. Cong. f. Hygiene, 1887.

<sup>15</sup> Coimbre Med., 1887-88.

<sup>16</sup> Phil. Med. News, 1888, i. 92.

<sup>17</sup> Sanitary News, 1888.

<sup>18</sup> Cincinn. Lancet-Clinic, 1888, p. 33.

dictory views. Thirty years ago Budd was a strenuous advocate of the contagiousness of the disease, while Murchison as strongly argued in favor of its *de novo* origin. Budd was correct, for it is contagious; but so was Murchison, in a measure, for the ability of the organism to live outside the body in almost any organic substance, and to resist months of freezing weather,<sup>19</sup> shows that it may propagate and be transported independently of any human agency, and so substantially arise *de novo*. That the typhoid bacillus may grow outside of the body, the poison remaining latent, as it were, even for many years, is not at all improbable; and the journals contain many instances like the following, which illustrate this point: Janeway,<sup>20</sup> in giving the history of the epidemic at Princeton in 1880, says that, with one exception, and that in a distant part of the town, there had been no typhoid in the place for forty-five years, when there were several cases in the same yard in which the disease first appeared in 1880. Low<sup>21</sup> narrates a case where it is probable that the bacilli continued to propagate in one place for thirty years. In cases even where the time is much shorter than this, the first infection may readily be lost sight of, and in this way are to be explained the many cases of apparently *de novo* origin. How numerous such cases are may be inferred from the answers received by Cabell<sup>22</sup> from sixty-eight correspondents in the rural parts of Virginia, fifty-eight of these replying that they believed in the *de novo* origin of the disease. Murchison thought that the poison was generated by filth, and hence called the disease pythogenic fever. He was both right and wrong. The typhoid

<sup>19</sup> N. Y. Med. Rec., April 2, 1887.

<sup>20</sup> N. J. State Board of Health. Rep., 1880, iv. p. 60.

<sup>21</sup> Br. Med. Jour., 1880, ii. p. 733.

<sup>22</sup> Trans. Am. Med. Ass. Phil., 1877, xxviii. p. 411.

organism grows on almost any dead vegetable or animal matter; better on the latter; but it grows best when such matter is not decomposing. But dead organized matter, except in freezing weather, speedily becomes filled with hosts of putrefactive organisms, and so the typhoid bacillus is obliged to struggle with them, and is hence found in filth, as we call it. But it does not prefer the company it keeps. It grows better alone on fresh material; but this it cannot get, except as it is prepared for it in laboratory cultures. It is probably the checking of putrefactive growths in the cool autumn weather which gives the typhoid bacilli a better chance, and makes the disease most prevalent just before the advent of frost. The typhoid bacillus is of slow growth, and hence the rapidly multiplying germs of putrefaction crowd it out in the hot summer season; but it grows well in the cool autumn, which is not so favorable for the other organisms.

There are three ways in which the typhoid organisms can gain access to the body: in the inspired air, in the drink, and in the food. Of course they must very frequently be taken into the lungs, but how often they pass from the lungs to the intestines is an open question. Probably rarely. Experimentally we know that they are rapidly destroyed in the blood of animals into which they have been injected, and they do not appear in human blood until it has been profoundly altered by the disease. It seems unlikely that they can often make their way into the pulmonary capillaries and reach the intestines alive. Clinical evidence, too, is against it. If typhoid fever spreads by the absorption of the organisms by the respiratory tract, we ought to find the disease constantly develop in hospital wards, where all sorts of patients are crowded together,

and usually little or no attempt at disinfection is made. But Murchison<sup>23</sup> says that in the London Fever Hospital, between 1848 and 1870, nearly six thousand cases of typhoid fever were treated, and during that time only four attendants upon them were attacked. Thirty-five hundred typhoid cases were treated in the same wards with over five thousand other patients, and not one of the latter contracted the disease. During this period almost no attempt at disinfection was made. Yet there is evidence to show that aerial infection does sometimes take place. Thus a case is reported where three young ladies, guests in a large hotel, who slept close by a privy containing typhoid stools, were attacked, although their food and drink were above suspicion.<sup>24</sup> None of the other guests were affected. At Mt. Desert, the persons who slept on the side of a hotel next to an open cesspool were attacked, while the other guests escaped.<sup>25</sup> At Princeton College, in 1880, the cases occurring in the college dormitories were shown to have a close relation to defective plumbing, which admitted infected air into the rooms.<sup>26</sup> The water was certainly not the source of the disease, and it is not likely that the students had much if any food in the rooms which could become contaminated. While in this city cases of typhoid seem often to be caused by contaminated air, it is almost always possible, and it seems to me probable, that it becomes effective by secondarily contaminating the food.

That well water may be the medium of infection in typhoid fever has been demonstrated beyond question. The epidemic at Pierrefonds, already

<sup>23</sup> Enteric Fever, p. 462.

<sup>24</sup> Soc. méd. des hôp., 1887.

<sup>25</sup> Boston M. & S. Jour., 1873, lxxxix. 421.

<sup>26</sup> N. J. State Board of Health Rap., 1880, iv. p. 65.

mentioned, is perhaps as good an instance as any. The much-quoted account by Dr. Flint of the polluted well at North Boston, which caused twenty-eight cases among those who drank from it, is another bit of conclusive evidence. Dr. Abbott, of the Massachusetts State Board of Health, a short time since told me of an epidemic at Canton Junction last spring, where a well belonging to a foundry was polluted from a cesspool fifty-three feet up the hill, which had received the stools of a typhoid patient the Fall before. The water caused a large number of cases among the workmen who used it, while the men in an adjoining building, who had other water, escaped. I can give no such striking instances as these in the history of Providence, though a number of times I have found typhoid among those who drank from a well known to be polluted with excrement, though not necessarily from a typhoid patient. As only a small proportion of our people use wells (there were only 1400 in use in 1885, while there were 12,500 service-pipes for the Pawtuxet water), it is possible that this may account for my inability to trace typhoid more frequently to this source. Nevertheless it is a fact that, with the exception of the past year, more cases of typhoid have occurred proportionally among the users of well water than among the users of Pawtuxet. And during the thirteen years since Pawtuxet water came into general use, the death-rate from typhoid has been nearly 40% less than in the preceding nineteen years. But the figures for the last thirteen years do not include the three epidemics which I believe were due to transient pollution of that water. There has been, as we should expect from the increasing interest in sanitary matters, a decrease in other parts of the State, but it has only been 25% as compared with 40% in the city.

While we can readily understand how the entrance of excreta from a case of typhoid into a well may infect the water so that those who drink it may become attacked, it is by some considered highly improbable that a running stream of considerable size can be thus infected. But the facts here, as in the case of wells, are incontestable. The history of Plymouth, Penn., is well known to you all. The stools from a single patient were thrown on the bank of the stream furnishing the water-supply of the town. The rains of the last of March washed these excreta into the water. This supply had for a time been shut off, but was turned on again on March 26. From April 5 to 9 over three hundred cases occurred, and ultimately twelve hundred out of a population of eight thousand sickened with this disease. I do not know the size of this stream, but, as it was sufficient for eight thousand persons, it probably had a flow of not less than 600,000 or 800,000 gallons a day. At Clermont and Mont-Ferrand,<sup>27</sup> in France, there was an epidemic in the Fall of 1886 which was traced to the pollution of the water-supply by the stools of a typhoid patient in August. Twenty days later the epidemic appeared, and at one time there were 231 cases among 40,000 people. Adjoining towns with a different water-supply escaped. The finding of the typhoid bacillus has been mentioned.

At Bordeaux,<sup>28</sup> in 1886-7, between Dec. 1 and Jan. 31, 841 cases were reported, mostly in those districts of the city which were supplied with water which was liable to contamination from typhoid stools.

At Geneva,<sup>29</sup> in 1884, there was an epidemic of

<sup>27</sup> Ann. d'hyg, Par., 1887, 3. s. xvii. 385.

<sup>28</sup> Jour. de méd. de Bordeaux, 1887-8, xvii. 273 *et seq.*

<sup>29</sup> Rev. méd. de la Suisse Romande, 1887, p. 378.

typhoid, lasting six months, clearly produced by the contamination of the water of the lake (which was used temporarily at that time) with sewage containing typhoid excreta. The largest number of cases reported in one month was 964. The population of Geneva is about 50,000. The facts of this epidemic indicated that the incubation of the disease is about two weeks.

At Zurich,<sup>30</sup> in 1884, there was an epidemic, traced to the public water-supply, lasting four months, and attacking 1621 out of 83,000 persons.

At Hamburg,<sup>31</sup> in 1885, there was an epidemic, beginning and ending abruptly, lasting several months, and including 2415 cases in a population of 550,000. One suburb, supplied with the same water (taken from the Elbe, and known to be polluted), suffered equally with Hamburg, while another section, continuous with the city, but with a separate water-supply, escaped.

At Cincinnati,<sup>32</sup> in 1887, there was an epidemic of typhoid which attracted considerable attention from the medical profession. This epidemic was traced to the public water-supply, which is taken from the Ohio river.

Numerous instances of a similar fatal pollution of large bodies of running water could be given, and it would be interesting to follow the steps by which the various epidemics were traced to their true origin; but lack of time forbids, and enough has been said to show that such pollution is by no means rare. We will now consider the influence of the public water-supply on typhoid fever in Providence.

During the latter part of November, 1888,

<sup>30</sup> Deut. Arch. f. k. Med., xxxix. p. 271.

<sup>31</sup> Deut. Vtjschr. f. öff. Gesundhtspfl., 1886, xviii. 537.

<sup>32</sup> Cincin. Lancet-Clinic, 1888, p. 33.

typhoid fever began to increase quite rapidly, and quite abruptly, at about the 23rd of the month. The increase culminated on Dec. 1st, when twenty-eight cases were reported, and the epidemic ceased almost as suddenly as it began, on Dec. 12th. The following are the cases reported during the weeks ending

Nov. 17	Nov. 24	Dec. 1	Dec. 8	Dec. 15	Dec. 22
6	11	24	139	84	16

There were fifteen deaths in November, forty-seven in December, and five in January. It will thus be seen that the epidemic was short, severe, and abrupt. The increase in typhoid was at this time confined to this city. It did not affect the neighboring towns. It was pretty evenly distributed throughout the city. As soon as these facts were determined, which was not till Dec. 1st, suspicion was at once thrown on the public water-supply as being the one cause most likely to affect the whole city, and not affect our near neighbors. Inquiry was made of the physicians in the valley of the Pawtuxet, to see if typhoid had been prevailing there. It was found that it had been prevailing from August to December 1st at Natick. It had attacked some twenty persons living in tenements near the river. The place was visited, and it was found that the inhabitants of the houses had been accustomed to throw slops and excrement on the banks of the stream, where they would be sure to wash in with a heavy rain, and where they might get in at other times. On Nov. 9 and 10 there was a heavy rain. Natick is situated three and a quarter miles above the pumping station, where the water is pumped directly into the Sockanosset reservoir, which holds ten or twelve days' supply. I am informed by the city engineer that two or three days might elapse (owing to the volume con-

tained in the mains) before water taken in at the pumps would actually reach the consumer. As ten to eighteen days is the probable incubation of typhoid, the ascertained facts are all in accord with the view that the epidemic was caused by the infection of the public water-supply. But another test was applied. Dr. Swarts<sup>33</sup> had shown that domestic filters are collectors and incubators of the microbes found in the water which passes through them. This fact was made use of, and several filters taken from houses where there was typhoid were examined for the bacilli. The water itself was only partially examined Dec. 1st. Attention was given to the filters because it was thought that they surely would contain the organism of the disease, if it had been in the water, even if it had then disappeared. Two filters were examined by Dr. Prudden, of New York, and the typhoid bacilli found in one. Two were examined by Dr. Ernst, of Boston, and the bacilli found in both. Two were examined by Dr. Swarts, and the typhoid bacilli found in neither. All observers found other organisms characteristic of human faeces.

There is no doubt that the disease which we had here was typhoid. This is shown by the clinical history, the mortality, the post-mortem appearances, and the finding of the characteristic bacilli in the spleen. The cases where the filters were removed were undoubtedly typhoid. There was no possibility of infection of the filters from the patient, particularly as in every instance they were removed before the patient had had any characteristic evacuations. These facts are a complete demonstration that this epidemic was caused by the pollution of our water-supply by the stools from typhoid patients.

<sup>33</sup> Trans. R. I. Med. Soc., 1887, p. 438.

It has been objected that it is incredible that such an enormous volume of water, probably six hundred million gallons per day at that time, could be infected by such a comparatively infinitesimal amount of fecal matter. It is also objected that if the water was at fault more persons would have been attacked.

But these two objections explain each other, for we know by experiment that the smaller the dose of an infective material the less likely is a person to succumb to it. Moreover, as we have seen, facts are not wanting to show that other cities have suffered in just the same way that we have. In 1882 and 1883 Providence suffered severely from typhoid fever, and as we had not at that time the means for thoroughly investigating the epidemic, its cause was not determined; but as it began suddenly October 23rd and caused nearly four hundred and fifty cases between that time and November 17th, when it somewhat abruptly ceased, and as it was general throughout the city, and as the disease was not unusually prevalent in other parts of the State, it is probable that it was due to the pollution of the Pawtuxet water. With the thawing which occurred in March the epidemic again made itself felt in about the same way as in the Fall, and was confined exclusively to the city. In the Fall of 1883 the rest of the State suffered, but the city did not. There is no evidence that our water-supply has been contaminated with the typhoid poison at any other than the times mentioned.

For several years Dr. Swarts, our medical inspector, has kept a watchful eye upon our milk-supply, but typhoid fever has in no instance been traced to it. Last year Dr. Swarts found that of three hundred and eighty-nine cases of typhoid in no instance were more than four persons supplied by the same

milkman. He found a very different state of things in Bristol last summer. In England it is not unusual to find the source of typhoid fever in the milk. Such instances have occurred in Providence, but as they were before I was superintendent of health I have no record of them.

If the air does not directly infect with typhoid, and if polluted water and milk furnish only a limited number of the deaths from typhoid which occur each year, how are the rest to be explained? It seems to me, from the recently acquired knowledge of this disease, that it is usually caused in somewhat the following manner. The dried spores of the bacillus are carried here and there by the wind or the numberless agencies by which the seeds of the higher plants are distributed, and, like the seeds, these spores take root, as it were, wherever they find a suitable soil. Animal and vegetable matter furnish such a soil, particularly the former. Privy-vaults, cesspools, swill-tubs, decayed wooden sink-spouts, filthy yards, vegetables in the cellar, furnish such organic matter. Fortunately for us this material is largely monopolized by the non-pathogenic organisms of putrefaction. But in the Fall, when the conditions of moisture and temperature are right, the organism grows in certain of these situations which are peculiarly favorable to it, and multiplies enormously. Some of these organisms thus produced find their way into the house and fall perhaps into milk put in the cellar, where it is cool, or upon cold potatoes on the pantry shelf only a few feet from an infected privy, or else, finding their way up the waste-pipe of a refrigerator which discharges on the moist ground or on an open drain, multiply at their leisure on the damp shelves that are rarely washed or aired, and now and then contaminate the custard pie or oatmeal that is put

there. The food is eaten without being cooked, the organisms sometimes escape the hostile action of the gastric juice, and we have a case of typhoid fever, which those who have paid little attention to bacteriology would be likely to quote as of *de novo* origin.



